RESPONSE TO EPA DRAFT DISPERSION MODELING ANALYSIS OF PSD CLASS I INCREMENT CONSUMPTION IN NORTH DAKOTA AND EASTERN MONTANA

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ACRONYMS AND ABBREVIATIONS

AQCR	Air Quality Control Region
AQRV	Air quality related values
ARM3	Acid Rain Mountain Mesoscale Model
CD	Compact disk
CEMS	Continuous emission monitor system
EPA	U.S. Environmental Protection Agency
FLM	Federal Land Managers
IWAQM	Interagency Workgroup on Air Quality Modeling
$\mu g/m^3$	Micrograms per cubic meter
NDDH	North Dakota Department of Health
NWS	National Weather Service
ppb	Parts per billion
PSD	Prevention of Significant Deterioration
SIP	State Implementation Plan
SO_2	Sulfur dioxide
TRNP	Theodore Roosevelt National Park

1.0 INTRODUCTION

The U.S. Environmental Protection Agency (EPA) released a draft dispersion modeling analysis of Prevention of Significant Deterioration (PSD) increment consumption in North Dakota and eastern Montana under a letter dated March 5, 2002. The draft report was entitled Dispersion Modeling Analysis of PSD Class I Increment Consumption in North Dakota and Eastern Montana and was dated January 2002. The March 5, 2002 letter accompanying the EPA document requested comments on the report within 30 days. The comment period was extended through April 29, 2002. Tetra Tech and ENSR International, on behalf of Basin Electric Power Cooperative and Dakota Gasification Company (Basin Electric), have conducted a technical and regulatory evaluation of the EPA draft dispersion modeling analysis outlined in the document.

The primary authors of this document are Robert Hammer of Tetra Tech, Kirk Winges of Tetra Tech, and Robert Paine of ENSR International. The qualifications of the primary authors are contained in their curriculum vitae attached as Appendix A.

The evaluation of EPA's draft dispersion modeling analysis of PSD increment consumption in North Dakota and eastern Montana was conducted and summarized in this document. The remainder of Section 1.0 discusses the history of issues, monitoring data, and organization of this response document.

1.1 HISTORY OF ISSUES

In 1999, the North Dakota Department of Health (NDDH) conducted a draft modeling analysis that predicted exceedances of the Class I PSD increments for sulfur dioxide (SO_2) in four Class I areas (NDDH 1999). The Class I areas addressed were Theodore Roosevelt National Park (TRNP) and Lostwood Wilderness Area in North Dakota and Medicine Lakes Wilderness Area and the Fort Peck Indian Reservation in Montana. In preliminary dispersion modeling activities, EPA has determined that there are predicted "violations" of the SO_2 PSD increment in the above named Class I areas. As a result, EPA has asserted that NDDH must adopt SO_2 emissions restrictions on North Dakota sources to eliminate draft predicted SO_2 increment "violations." EPA has threatened to conduct a State Implementation Plan (SIP) call if appropriate steps are not adopted to eliminate predicted "violations."

In previous permitting efforts of North Dakota sources, the Federal Land Managers (FLM) issued variances to sources where computer air dispersion modeling studies of SO_2 emissions predicted exceedances of certain PSD Class I increments but would not result in significant deterioration of air quality related values (AQRV) with in the Class I Areas. The variances were issued despite modeled

predictions that impacts from the increases in SO_2 emissions contributed to exceedances of Class I PSD increments. Variances were issued by the FLM of TRNP and Lostwood Wilderness Area; the NDDH subsequently issued the necessary air quality permits for the construction of the proposed sources.

EPA has asserted that, despite the issuance of the variances previously granted to specific North Dakota sources, compliance with the Class I SO_2 increments must still be demonstrated for all SO_2 increment consuming emissions. EPA contends that it is the responsibility of the State of North Dakota to assure that SO_2 Class I PSD increments are maintained, including impacts from the North Dakota sources which were granted variances for increases in SO_2 emissions. This is in contrast to EPA's past position and practice that accepted the variances granted in North Dakota as demonstrating compliance with applicable regulations.

In a March 13, 2001 letter to EPA, NDDH committed to refine the SO_2 increment consumption modeling analysis and, if required, to subsequently adopt any necessary revisions to the SIP to address increment "violations." In developing a modeling protocol, EPA and NDDH could not fully agree on the appropriate approach (including the types of input data) to be used in the final modeling. NDDH has conducted their own version of modeling released for comment in March 2002. EPA elected to conduct modeling using its own approach that was summarized in the document for which this response has been drafted.

1.2 MONITORING DATA

Monitoring data in Class I areas have shown steady decreases in SO_2 concentrations, indicating possible increment expansion of emission sources or stable low levels. However, 1999 and 2000 NDDH modeling analyses showed increment exceedances in Class I areas, indicating increment consumption. The inconsistency between measured and modeled SO_2 concentrations is another concern for the accuracy of the results presented in the EPA modeling.

1.3 ORGANIZATION

This document is organized into nine sections. Section 2.0 discusses how the current version of CALPUFF emerged as EPA's proposed long-range transport model and limitations in its use. Section 3.0 provides a discussion of emissions inventory issues. Section 4.0 reviews use of meteorological data. Section 5.0 contains a discussion of receptors. CALPUFF modeling application is evaluated in

Section 6.0. Section 7.0 reviews the model results. Section 8.0 summarizes the document and presents conclusions. A bibliography is included as Section 9.0.

2.0 CALPUFF/CALMET MODELING SYSTEM

This section discusses the history behind CALPUFF's selection as a proposed EPA guideline model. Although EPA is on a path to promulgate CALPUFF, there are a number of model limitations, also discussed in this section, that should be understood in the context of this current application.

2.1 CALPUFF AS A PROPOSED EPA GUIDELINE MODEL

EPA's Guideline on Air Quality Models currently recommends no model for long-range transport, but allows the use of MESOPUFF II on a case-by-case basis. MESOPUFF II has been approved and used in North Dakota for several years after hearings were conducted on its applicability that involved EPA, NDDH, and the public.

CALPUFF (Scire 2000) is the first dispersion model formally proposed by EPA as a preferred guideline model for assessing long-range transport impacts (covering distances beyond 50 kilometers) that may be generally used without a case-by-base justification. In the early 1990s, EPA and the FLMs formed an Interagency Workgroup on Air Quality Modeling (IWAQM) to produce a consistent approach to assess impacts in Federal Class I Areas and developed guidance for the CALPUFF model. A brief history of the IWAQM process to select long-range transport modeling techniques is provided below.

The IWAQM plan of model development involved a phased approach. Phase 1 consisted of reviewing EPA guidance and recommending an interim modeling approach to meet the immediate need for a long-range transport model for ongoing permitting activity. In developing a Phase 2 recommendation, the IWAQM workgroup reviewed other available operational models and made a recommendation of the most appropriate modeling techniques.

Given the practical limitations of resources and hardware, the IWAQM Phase 1 interim recommendations (EPA 1993) were designed to provide the best approach from existing "off-the-shelf" techniques. Two candidate models were assessed, the MESOPUFF II model (EPA 1994) and the Acid Rain Mountain Mesoscale Model (ARM3) (Morris 1988). Upon careful examination of both models, IWAQM discovered coding errors in the ARM3, which potentially invalidated its previous evaluations. IWAQM's Phase 1 recommendation was to use, on a case-by-case basis, the Lagrangian puff model, MESOPUFF II, to evaluate the impacts of pollutants from sources located more than 50 kilometers and up to several hundred kilometers from Class I areas. In addition, the State of North Dakota was well ahead of

IWAQM, having adopted MESOPUFF II more than 10 years before the formation of IWAQM, in the early 1980s, to be used for assessing PSD Class I impacts in North Dakota.

For the Phase 1 IWAQM recommendation, MESOPUFF II was deemed suitable for conducting single source impact analyses and, in some circumstances, cumulative impact analyses. Since the dispersion characterizations in MESOPUFF II were not designed to handle local-scale dispersion effects, it was recognized that the MESOPUFF II results would frequently need to be combined with the results from other modeling techniques used to estimate concentrations from sources closer than 50 kilometers to a receptor area. The Phase 1 recommendation was structured to satisfy case-by-case EPA modeling guideline criteria for cases where there is no preferred model, including long-range transport applications.

By restricting the models considered for Phase 1 to "off-the-shelf" techniques, IWAQM recognized certain limitations. These included a lack of consideration of the effects of terrain on the long-range transport and dispersion (MESOPUFF II does not consider terrain effects), an underestimation of the conversion of SO_2 to sulfate when polluted air interacts with clouds, and a possible overestimation of particulate nitrate when a limited number of sources are considered. Nonetheless, IWAQM considered the techniques to be a significant improvement to those previously used, in that previous techniques ignored many of the processes important to the assessment of air quality impacts in Class I areas.

Not long after the release of the Phase 1 recommendation, EPA sponsored the Sixth Modeling Conference, held August 9 and 10, 1995 in Washington, D.C. One of the main topics at this 2-day event was a review of the IWAQM Phase 1 recommendation and a summary of work in progress; review comments were provided by several groups. At the conference, IWAQM presented a long-range trajectory comparison that suggested that use of mesoscale meteorological analyses of wind fields provided a significant improvement in the accord of modeled and observed trajectories. The IWAQM specifically endorsed the use of mesoscale meteorological analyses that employ data assimilation, such as the use of MM4 data (Anthes 1987). The IWAQM concluded that the Phase 1 recommendation to use the MESOPUFF II modeling system should be replaced with a Phase 2 recommendation to use the CALMET/CALPUFF modeling system. This Phase 2 model was a relatively new Lagrangian puff modeling system that had additional algorithms to provide simulation of local-scale short-range dispersion using methods already endorsed by the EPA. Thus, this newer modeling system could allow one model to be used for all sources in an analysis, regardless of the transport distance involved. However, EPA still retains the recommendation that a short-range model such as ISCST3 be used within 50 kilometers of a source. Significant improvements afforded by CALPUFF over MESOPUFF II were

improved terrain handling, more vertical resolution in the wind field definition, and better handling of plume chemistry.

As a result of the IWAQM recommendation, EPA has proposed CALPUFF as a model for long-range transport applications (with source-receptor distances beyond 50 kilometers). EPA also proposes that CALPUFF be considered on a case-by-case basis for short-range applications involving "complex winds," where straight-line steady-state plume transport models would not likely work well. In the present North Dakota application involving SO_2 impacts at the PSD Class I areas, most of the sources being modeled are beyond 50 kilometers from the Class I areas. However, several of the oil and gas producing sources are within 50 kilometers. According to current and proposed guidance, these sources, in our judgment, should be run with the ISCST3 or AERMOD model, because the terrain involved is not so severe as to make short-range modeling applications invalid.

EPA proposed the use of CALPUFF as a preferred guideline model for long-range transport applications in a *Federal Register* notice on April 21, 2000. There was a subsequent comment period that ended in August 2000. In June 2001, Mr. Joseph Tikvart of EPA's Office of Air Quality Planning and Standards provided a presentation at the 2001 meeting of the Air & Waste Management Association. His comments on the EPA's forthcoming rulemaking on CALPUFF that are relevant for this application were that:

- The scientific basis for CALPUFF is sound and the model provides substantial transport and dispersion capabilities.
- The accuracy of CALPUFF is sufficient for long-range transport applications, and for case-by-case complex wind applications.
- A protocol for individual complex applications is desirable.
- If, using National Weather Service meteorological data, a 5-year data set should be used. Fewer years of data (but at least 1 year) should be used from the output of prognostic mesoscale models such as MM4 or MM5.
- AERMOD-like dispersion options should be the default, but other settings/guidance must wait for additional experience.
- EPA is hoping to improve certain elements of the CALPUFF system model documentation prior to promulgation.

2.2 LIMITATIONS OF CALPUFF

Although EPA is on a path to promulgate CALPUFF as a guideline model for long-range transport applications, there are a number of implementation issues and model limitations that should be understood and resolved prior to its regulatory use, especially in this case where very significant decisions are involved. Generating wind fields with CALMET, using multiple sites for surface and upper air data, introduces a number of technical challenges for the model user that should be resolved prior to its regulatory use for imposing significant control expenditures.

Although many technical model options have default selections, site-specific considerations are often necessary, and there is relatively little guidance available on the considerations that need to be taken into account in making these selections. NDDH has done an extensive review of the model options for the CALPUFF modeling of impacts at PSD Class I areas in the state. Additional modeling options that are worthy of consideration are discussed later in this report.

A limited number of evaluations of CALPUFF has been completed by EPA. The following summary information is provided in Section 2.3.2 and in Appendix D of the IWAQM Phase 2 Summary Report. It indicates distance and time-travel limitations regarding CALPUFF applications.

From Section 2.3.2 of the IWAQM Phase 2 report:

> "...it appears that CALPUFF provides reasonable correspondence with observations for transport distances of order 100 kilometers. Most of these comparisons involved concentration values averaged over 5 to 12 hours. The CAPTEX comparisons, which involved comparisons at receptors that were 300 kilometers to 1000 kilometers from the release, suggest that CALPUFF tends to overestimate surface concentrations by a factor of 3 to 4. Use of the puff splitting option in CALPUFF might have improved these comparisons, but there are serious conceptual concerns with the use of puff dispersion at very long-range transport (300 kilometers and beyond). As the puffs enlarge due to dispersion, it becomes problematic to characterize the transport by a single wind vector, as significant wind direction shear may well exist over the puff dimensions."

From Appendix D of the IWAQM Phase 2 report:

> "...The IWAQM concludes that CALPUFF can be recommended as providing unbiased estimates of concentration impacts for transport distances of order 200 kilometers or less, and for transport times of order

> 12 hours or less. For larger transport times and distances, our experience thus far is that CALPUFF tends to underestimate the horizontal extent of the dispersion and hence tends to overestimate the surface-level concentration maxima. This does not preclude the use of CALPUFF for transport beyond 300 kilometers, but it does suggest that results in such instances be used cautiously and with some understanding."

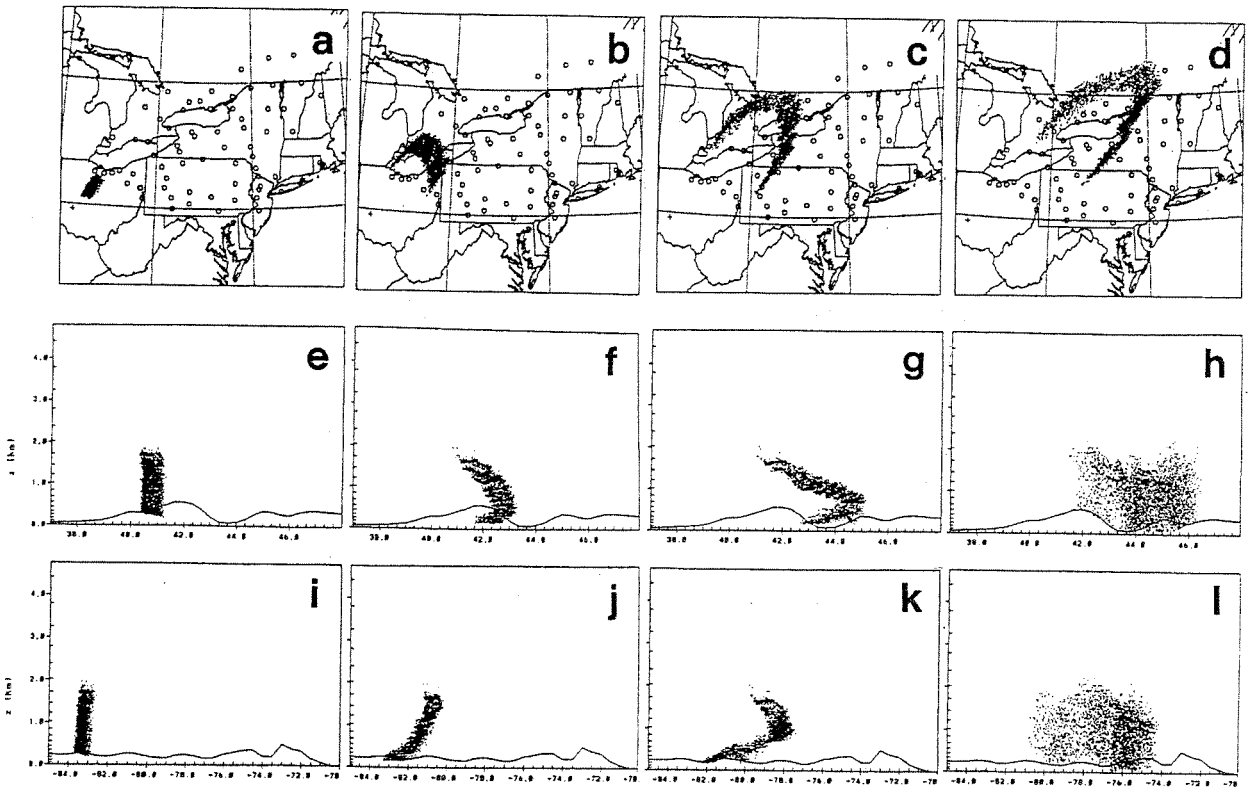
It appears from the above IWAQM findings that, at a distance of 200 kilometers, the CALPUFF modeling estimates would likely have an overprediction tendency somewhere between the unbiased ratio of 1 at 100 kilometers and the ratio of 3 to 4 at 300 kilometers and beyond. An overprediction tendency at a distance of 200 kilometers of about 2 may be expected. This expectation is explored further in Section 6.0 of this report with the analysis of the NDDH evaluation of CALPUFF using data from the year 2000.

One aspect of mesoscale dispersion modeling that could help to explain the potential CALPUFF overpredictions involves vertical wind shear and its effects upon pollutant dispersion. A paper delivered at the Eighth Joint Conference on Applications of Air Pollution Meteorology in 1994 discussed the importance of wind shear effects on enhancing, or even dominating, the horizontal dispersion during long-range transport. This presentation (Moran and Pielke 1994) showed, with a numerical particle model, that vertical shear of the horizontal flow can result in pollutants at different levels being advected at different speeds or in different directions. This situation is most likely to occur during the nighttime hours, when the vertical mixing in the atmosphere is often suppressed by stable thermal stratification. After the shape of a pollutant cloud becomes distorted by wind shear effects, subsequent or delayed vertical mixing will greatly enhance the horizontal spread of the cloud when it is mixed to the ground (Figure 2-1) (Moran and Pielke 1994). Moran and Pielke conclude that "the neglect of wind shear by mesoscale atmosphere dispersion models can result in significant errors in the prediction of tracer cloud size, shape, centroid location, and surface footprint if the cloud has experienced a sequence of at least two stability regimes." Figure 2-1 shows that CALPUFF might tend to assume a plume spread as depicted in panels e or i while the actual plume spread after the morning inversion breakup is likely to better resemble panels h and l. Since CALPUFF may not have the capability to fully characterize the vertical shear effects, it is subject to the effect of underestimating the plume footprint and overestimating the concentration.

CALPUFF does have a puff splitting algorithm that is designed to respond to horizontal wind shears across a puff. In effect, the algorithm causes puffs to be subdivided and the "daughter" puffs sent along different trajectories, leading to increased effective rate of puff dispersion and lower ground-level concentrations. There may be complex interactions between various parts of the CALPUFF modeling system and their cumulative effects upon this critically important puff splitting algorithm. For example, the way in which surface and upper level winds are weighted, extrapolated, and otherwise manipulated in CALMET can have a significant bearing on how effective the puff splitting algorithm works.

FIGURE 2-1

DEPICTION OF A POLLUTANT CLOUD MOVEMENT EMITTED DURING THE CAPTEX EXPERIMENT



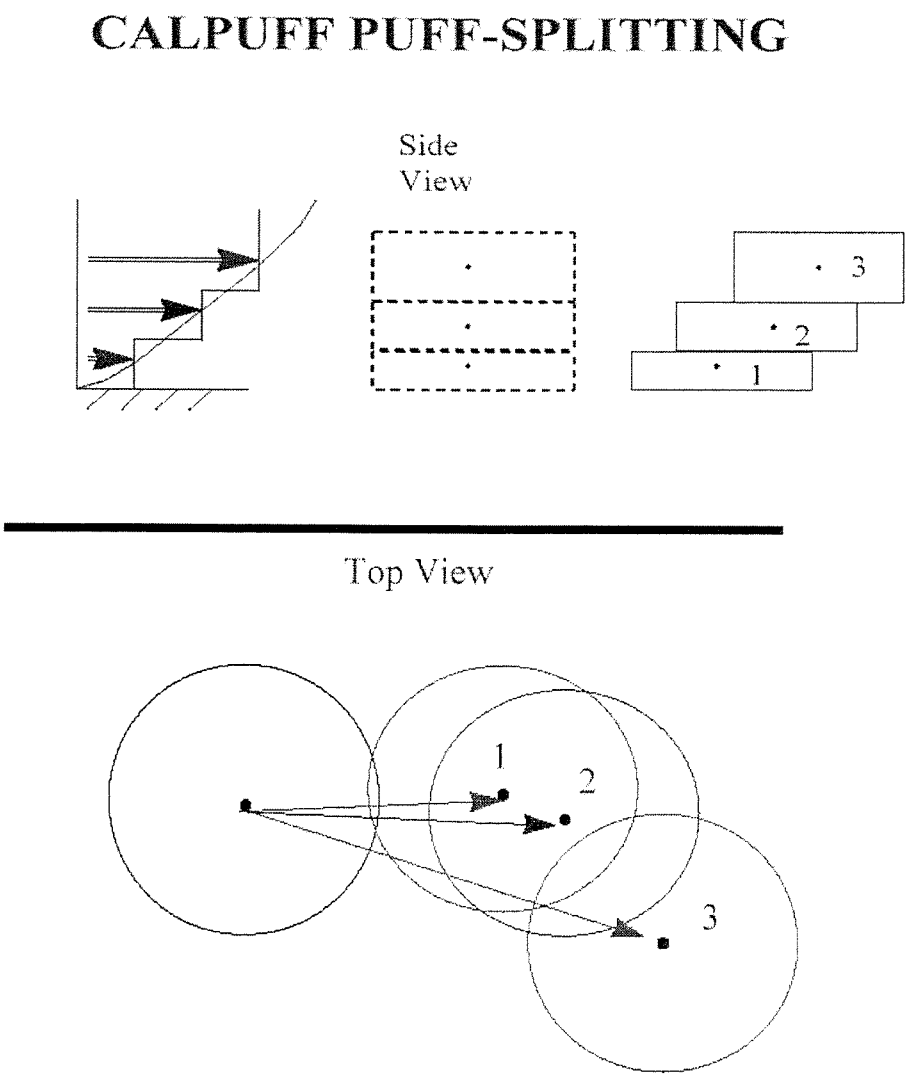
As addressed in the 2000 CALPUFF User Manual, the algorithm should split the puff into three parts and send these new puffs in different directions, thereby effectively increasing the plume spread (Figure 2-2). However, the complex interactions between the construction of the wind field and the dispersion model may be such that seemingly unrelated processing decisions in CALMET (such as extrapolation of surface winds aloft, which could artificially reduce wind shear in the model) can significantly affect the dispersion results in CALPUFF, especially as they pertain to puff splitting. It is also evident from an inspection of the CALPUFF code that while the horizontal splitting in CALPUFF involves a computation of horizontal wind shear, this is not the case with the all-important vertical puff splitting. The vertical puff splitting tests merely check on the status of the puff elevation with respect to past and present mixing heights that the puff is or has experienced. Therefore, the full potential of vertical splitting may not be realized in CALPUFF, resulting in lost opportunities to respond to vertical wind shear.

The IWAQM Phase 2 report describes comparisons of CALPUFF predictions to tracer study observations in Section 4.6 of that report. The experiences encountered among the various experimental sites for CALPUFF can be summarized as follows:

- For individual events, the plume's trajectory missed the target by an angle on the order of 20 degrees, with considerable scatter about this value.
- In several cases, the modeled plumes had higher central maximum concentrations and narrower dispersion than the observations indicated.
- Due to the relatively narrow plumes in CALPUFF, the directional error could mean significant changes in the locations of predicted impacts. In some cases, this deficiency was countered by using a network of receptors rather than a single point prediction.

FIGURE 2-2

DEPICTION OF CALPUFF HANDLING OF PUFF SPLITTING



3.0 EMISSIONS INVENTORY

This section describes how EPA compiled the emissions inventory for their January 2002 modeling. The emission inventory used for the EPA modeling included only major sources and excluded all minor sources. Most of the minor sources surrounding the Class I areas are oil and gas facilities. Since the North Dakota minor source baseline year, the practice of flaring has decreased at these facilities and SO_2 emissions have subsequently decreased. The decrease in SO_2 emissions results in PSD increment expansion within the impact area of these nearby oil and gas facilities. The SO_2 emissions due to flaring are largely undocumented and are believed to represent an underestimate in the baseline emissions from the minor sources.

Because the oil and gas facilities are relatively close to the North Dakota Class I areas, and because there are so many of them, a significant impact on the Class I areas is possible. EPA's modeling report indicates that these sources will be incorporated into the final modeling analysis. However, the results of the EPA modeling analysis completed in January 2002 cannot be considered valid without the inclusion of minor source emissions.

EPA's process for determining current and baseline emissions and use of the ratio method of estimating baseline emissions are two major issues of concern in EPA's emission inventory.

3.1 CURRENT EMISSIONS

The current emission inventory for the EPA modeling analysis was compiled for major facilities currently in operation. The major sources included in the current inventory are: Antelope Valley Station, Coal Creek Station, CELP Boiler, Colstrip, Coyote Station, Greatplains Synfuels, Grasslands Gas, Heskett Station, Little Knife Gas Plant, Leland Olds, Milton R. Young Station, and Stanton Station. Of these 12 major sources, eight are power plants (Antelope Valley Station, Coal Creek Station, Colstrip, Coyote Station, Heskett Station, Leland Olds Station, Milton R. Young Station, and Stanton Station).

The current year inventory for the power plants in the EPA study is primarily based on 1999 and 2000 continuous emission monitor system (CEMS) data from major sources. CEMS data were obtained from EPA's Acid Rain Program. No CEMS data were available for Grasslands Gas, Little Knife Gas Plant, or the Greatplains Synfuels Plant. Because there were no CEMS data available for these facilities, EPA used emission-estimating techniques similar to those used by NDDH in its 1999 study.

The Mandan Refinery is a major source currently in operation and less than 250 kilometers from the Class I areas in question. However, it was not included in the EPA baseline or current source inventory. Facility-wide emissions at the Mandan Refinery would likely be applicable to this study since the refinery is within the 250-kilometer radius of some of the Class I areas. The refinery existed during the baseline date, and still exists today. Net changes from the Mandan Refinery show a decrease in emissions.

3.2 BASELINE EMISSIONS

The baseline emission inventory for the EPA modeling analysis was compiled for major facilities that were in operation as of the minor source baseline date. The minor source baseline date is specific to the area being modeled, and it occurs after the pollutant-specific trigger date, which EPA defines as August 7, 1977 for SO_2. The minor source baseline date is defined as the earliest date after the trigger date that a complete PSD permit application was submitted for a proposed major stationary source or a major modification at an existing stationary source. In North Dakota Air Quality Control Region (AQCR) 172, the first PSD permit application after the SO_2 trigger date was submitted on December 17, 1977. According to EPA their baseline emission inventory was compiled to reflect sources within 250 kilometers of each Class I area as of December 17, 1977.

EPA initially described their baseline inventory as based on actual emissions averaged over the 2-year period 1976-1977. EPA may not simply assume without inquiry that the years 1976 and 1977 are representative of normal operations for all sources within 250 km of the Class I areas. In fact, those years are not representative for many sources.

EPA's unsubstantiated assumption with respect to normal operations alone invalidates much of the emissions inventory that EPA has used for baseline determinations. NDDH has made detailed inquiry into this issue, and is holding hearings beginning on May 6 to determine what is representative of normal operations of the sources significantly affecting the Class I areas. As with the modeling itself, the responsibility for determining what is representative of normal operations is primarily a state responsibility, as is the decision on whether to use 2-year representative or source-specific allowable emissions.

As noted in Section 3.1, the Mandan Refinery was a baseline year source and was inappropriately excluded from the EPA modeling.

3.3 INCREMENT EXPANDING EMISSIONS

The net effect of emission changes at the Mandan Refinery has been a reduction in SO_2 emissions. The increment expanding emissions EPA used in the modeling analysis would have been higher if the Mandan Refinery had been included in the EPA analysis. Although the extent of the effect of Mandan Refinery emissions on this Class I increment analysis is unknown, it is clear that the higher baseline emissions from the Mandan Refinery should cause some increment expansion.

In addition to the missing Mandan Refinery emissions, the increment expanding sources were modeled with annual emission rates, while the other major sources were modeled with data developed to represent short-term emission rates. Using annual emissions for some sources and short-term emissions for others is inconsistent and should be re-examined.

3.4 USE OF CONSISTENT METHODOLOGY

EPA's modeling document states that a consistent methodology should be used in determining baseline emission estimates and the impacts of current emissions, but then compares the results of two different methodologies, AP-42 (a standard emission factors technique based on averaging test results at several sources) and CEMS (a continuous emission monitoring system, employing adjusted site-specific results.) As demonstrated in the attached letter filed by Basin Electric with NDDH dated September 7, 2001 on pages 29 to 32, AP-42 consistently underpredicts emissions for Basin Electric's Leland Olds plant, and CEMS overpredicts emissions. The result is to estimate increment consumption solely due to a difference in the method of estimation. It is evident from Figure 6 and Figure 7 of the September 7, 2001 letter that if either consistent CEMS or AP-42 estimates are used for baseline and current emissions, the increment exceedances due to the source nearly disappear.